

CRS Report for Congress

The Manhattan Project, the Apollo Program, and Federal Energy Technology R&D Programs: A Comparative Analysis

September 3, 2008

Deborah D. Stine
Specialist in Science and Technology Policy
Resources, Science, and Industry Division



Prepared for Members and
Committees of Congress

The Manhattan Project, the Apollo Program, and Federal Energy Technology R&D Programs: A Comparative Analysis

Summary

Some policymakers have concluded that the energy challenges facing the United States are so critical that a concentrated investment in energy research and development (R&D) should be undertaken. The Manhattan project, which produced the atomic bomb, and the Apollo program, which landed American men on the moon, have been cited as examples of the success such R&D investments can yield. Investment in federal energy technology R&D programs of the 1970s, in response to two energy crises, have generally been viewed as less successful than the earlier two efforts. This report compares and contrasts the three initiatives.

In 2007 dollars, the cumulative cost of the Manhattan project over 5 fiscal years was approximately \$21 billion; of the Apollo program over 14 fiscal years, approximately \$96 billion; of post-oil shock energy R&D efforts over 35 fiscal years, \$115 billion. A measure of the nation's commitments to the programs is their relative shares of the federal outlays during the years of peak funding: for the Manhattan program, the peak year funding was 1% of federal outlays; for the Apollo program, 2.2%; and for energy technology R&D programs, 0.5%. Another measure of the commitment is their relative shares of the nation's gross domestic product (GDP) during the peak years of funding: for the Manhattan project and the Apollo program, the peak year funding reached 0.4% of GDP, and for the energy technology R&D programs, 0.1%.

Besides funding, several criteria might be used to compare these three initiatives including perception of the program or threat, goal clarity, and the customer of the technology being developed. By these criteria, while the Manhattan project and the Apollo program may provide some useful analogies for thinking about an energy technology R&D initiative, there are fundamental differences between the forces that drove these historical R&D success stories and the forces driving energy technology R&D today. Critical differences include (1) the ability to transform the program or threat into a concrete goal, and (2) the use to which the technology would be put. On the issue of goal setting, for the Manhattan project, the response to the threat of enemy development of a nuclear bomb was the goal to construct a bomb; for the Apollo program, the threat of Soviet space dominance was translated into a specific goal of landing on the moon. For energy, the response to the problems of insecure oil sources and high prices has resulted in multiple, sometimes conflicting, goals. Regarding use, both the Manhattan project and the Apollo program goals pointed to technologies primarily for governmental use with little concern about their environmental impact; for energy, in contrast, the hoped-for outcome depends on commercial viability and mitigation of environmental impacts from energy use.

Although the Manhattan project and the Apollo program may provide some useful analogies for funding, these differences may limit their utility regarding energy policy. Rather, energy technology R&D has been driven by at least three not always commensurate goals — resource and technological diversity, commercial viability, and environmental protection — which were not goals of the historical programs.

Contents

The Manhattan Project	1
The Apollo Program	2
Energy Technology Research and Development	3
Comparative Analysis of the Manhattan Project, the Apollo Program, and Federal Energy Technology R&D	6
Funding	6
Threat Perception	6
Goal Clarity	9
Technology Customer	9
Implications for Congress	10

List of Figures

Figure 1. Comparison of Consumer Transportation Oil Cost and DOE Energy Technology R&D Funding, 1973-2005	5
Figure 2. Annual Funding for Manhattan Project, Apollo Program, and DOE Energy Technology R&D Program	8

List of Tables

Table 1. Cumulative and Annual Average Program Year Funding for the Manhattan Project, the Apollo Program, and DOE Energy Technology R&D Program .	7
--	---

The Manhattan Project, the Apollo Program, and Federal Energy Technology R&D Programs: A Comparative Analysis

Some policymakers have concluded that the energy challenges facing the United States are so critical that a concentrated investment in energy research and development (R&D) should be undertaken.¹ The Manhattan project, which produced the atomic bomb, and the Apollo program, which landed American men on the moon, have been cited as examples of the success such R&D investments can yield. Investment in federal energy technology R&D programs of the 1970s, in response to two energy crises, have generally been viewed as less successful than the earlier two efforts. This report compares and contrasts the goals of, and the investments in, the three initiatives, which may provide useful insights for Congress as it assesses and debates the nation's energy policy.

The Manhattan Project

The Manhattan project took place from 1942 to 1946.² Beginning in 1939, some key scientists expressed concern that Germany might be building an atomic weapon and proposed that the United States accelerate atomic research in response. Following the Pearl Harbor attack in December 1941, the United States entered World War II. In January 1942, President Franklin D. Roosevelt gave secret, tentative approval for the development of an atomic bomb. The Army Corps of Engineers was assigned the task and set up the Manhattan Engineer District to manage the project. A bomb research and design laboratory was built at Los Alamos, New Mexico. Due to uncertainties regarding production effectiveness, two possible fuels for the reactors were produced with uranium enrichment facilities at Oak Ridge, Tennessee, and plutonium production facilities at Hanford, Washington. In

¹ Examples in the 110th Congress include bills such as the New Manhattan Project for Energy Independence (H.R. 6260); the PROGRESS Act (H.R. 1300); the Gas Price Reduction Act of 2008 (S. 3202); the Apollo Energy Independence Act of 2008 (H.R. 6385); the Comprehensive Energy Exploration, Price Reduction, and Renewable Energy Investment Act of 2008 (H.R. 6412); and the New Apollo Energy Act of 2007 (H.R. 2809). For a further discussion of this issue, see CRS Report RL34621, *Capturing CO₂ from Coal-Fired Power Plants: Challenges for a Comprehensive Strategy*, by Larry Parker, Peter Folger, and Deborah D. Stine.

² U.S. Department of Energy, Office of History and Heritage Resources, “The Manhattan Project: An Interactive History,” [<http://www.cfo.doe.gov/me70/manhattan/1939-1942.htm>]. F.G. Gosling, *The Manhattan Project: Making the Atomic Bomb*, January 1999 edition (Oak Ridge, TN: Department of Energy).

December 1942, Roosevelt gave final approval to construct a nuclear bomb. A bomb using uranium as fuel was successfully tested south of Los Alamos in July 1945. In August 1945, President Truman decided to use the bomb against Japan at two locations. Japan surrendered a few days after the second bomb attack. At that point, the Manhattan project was deemed to have fulfilled its mission, although some additional nuclear weapons were still assembled. In 1946, the civilian Atomic Energy Commission was established to manage the nation's future atomic activities, and the Manhattan project officially ended.

According to one estimate, the Manhattan project cost \$2.2 billion from 1942 to 1946 (\$21 billion in 2007 dollars), which is much greater than the original cost and time estimate of approximately \$148 million for 1942 to 1944.³ General Leslie Groves, who managed the Manhattan project, has written that Members of Congress who inquired about the project were discouraged by the Secretary of War from asking questions or visiting sites.⁴ After the project was under way for over a year, in February 1944, War Department officials received essentially a "blank check" for the project from Congressional leadership who "remained completely in the dark" about the Manhattan project, according to Groves and other experts.⁵

The Apollo Program

The Apollo program, FY1960 to FY1973, encompassed 17 missions, including six lunar landings.⁶ NASA was created in response to the Soviet launch of Sputnik

³ Richard G. Hewlett and Oscar E. Anderson, Jr., *A History of the United States Atomic Energy Commission: The New World, 1939/1946, Volume I*, (University Park, PA: The Pennsylvania State University Press, 1962). Appendix 2 provides the annual Manhattan project expenditures. These costs were adjusted to 2007 dollars using the price index for gross domestic product (GDP), available from the Bureau of Economic Affairs, National Income and Product Accounts Table webpage, Table 1.1.4, at [<http://www.bea.gov/bea/dn/nipaweb/>].

⁴ Leslie R. Groves, *Now it Can be Told: The Story of the Manhattan Project* (New York: Harper & Brothers, 1962).

⁵ Ibid., Kevin O'Neil, "Building the Bomb," Chapter 1 in Stephen I. Schwartz (ed.), *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940* (Washington, DC: Brookings Institution Press, 1998), pp. 58-59.

⁶ Richard Orloff, National Aeronautics and Space Administration (NASA), *Apollo By The Numbers: A Statistical Reference*, NASA SP-2000-4029, 2004 web update at [http://history.nasa.gov/SP-4029/Apollo_00_Welcome.htm]. There is some difference of opinion regarding what activities comprised the Apollo program, and thus when it began and ended. For example, two different cost figures are provided on NASA's website. This is probably because some analysts include the first studies for Apollo, Skylab, and the use of Apollo spacecraft in the Apollo-Soyuz Test Project. The Orloff analysis includes the first studies of Apollo, but not Skylab (1973-74) or Soyuz (1975) activities. Another NASA analysis provides the cost as \$25.4 billion, but provides no details as to how the cost were determined. See Roger D. Launius, NASA, *The Legacy of Project Apollo* at [<http://history.nasa.gov/ap11-35ann/legacy.html>].

in 1958 and began operation in 1959.⁷ Although preliminary discussions regarding the Apollo program began in 1960, Congress did not decide to fund it until 1961 after the Soviet Union became the first nation to launch a human into space. The goals of the Apollo program were

- To land Americans on the Moon and return them safely to Earth;
- To establish the technology to meet other national interests in space;
- To achieve preeminence in space for the United States;
- To carry out a program of scientific exploration of the Moon; and
- To develop man's capability to work in the lunar environment.⁸

The program included a three-part spacecraft to take two astronauts to the Moon surface, support them while on the Moon, and return them to Earth.⁹ Saturn rockets were used to launch this equipment. In July 1969, Apollo 11 achieved the goal of landing Americans on the Moon and returning them safely to Earth. The last lunar landing took place in December 1972.

The Apollo program was only one part of NASA's activities during this period. NASA's peak funding during the Apollo program occurred in FY1966 when its total funding was \$4.5 billion (in current dollars), of which \$3.0 billion went to the Apollo program.¹⁰ According to NASA, the total cost of the Apollo program for FY1960-FY1973 was \$19.4 billion (\$95.7 billion in 2007 dollars).¹¹ The activities with the greatest cost were the Saturn V rockets (\$6.4 billion) followed by the Command and Service Modules (\$3.7 billion), the Lunar Modules (\$2.2 billion), and Manned Space Flight Operations (\$1.6 billion).

⁷ For more information, see CRS Report RL34263, *U.S. Civilian Space Policy Priorities: Reflections 50 Years After Sputnik*, by Deborah D. Stine.

⁸ NASA, Kennedy Space Center, "Project Apollo," webpage, at [<http://www-pao.ksc.nasa.gov/kscpao/history/apollo/apollo.htm>]. A list of the top ten Apollo scientific discoveries as determined by the Smithsonian Institution is at [<http://www.nasm.si.edu/collections/imagery/apollo/apollo10.htm>].

⁹ NASA, Kennedy Space Center, "Project Apollo," webpage, at [<http://www-pao.ksc.nasa.gov/kscpao/history/apollo/apollo.htm>]. The three parts were the command module (CM), the crew's quarters and flight control section; the service module (SM) for the propulsion and spacecraft support systems (when together, the two modules are called CSM); and the lunar module (LM).

¹⁰ The funding data is available at [<http://history.nasa.gov/SP-4214/app2.html#1965>]. It is based on information in NASA, *The Apollo Spacecraft - A Chronology*, NASA Special Publication-4009, at [<http://www.hq.nasa.gov/office/pao/History/SP-4009/contents.htm>]. This data is from Volume 4, Appendix 7, at [<http://www.hq.nasa.gov/office/pao/History/SP-4009/v4app7.htm>].

¹¹ Richard Orloff, *Apollo By The Numbers: A Statistical Reference*, NASA SP-2000-4029, 2004 web update, at [http://history.nasa.gov/SP-4029/Apollo_00_Welcome.htm]. The funding data is available at [http://history.nasa.gov/SP-4029/Apollo_18-16_Apollo_Program_Budget_Appropriations.htm]. It is based on information in NASA, *The Apollo Spacecraft - A Chronology*, NASA Special Publication-4009, at [<http://www.hq.nasa.gov/office/pao/History/SP-4009/contents.htm>].

Energy Technology Research and Development

The Arab oil embargo of 1973 (the “first” energy crisis) put energy policy on the national “agenda.” At that time, Americans began to experience rapidly rising prices for fuel and related goods and services.¹² Until then, energy R&D had been focused on the development of nuclear power under the Atomic Energy Commission (AEC). After the Manhattan project ended, Congress had established the AEC to manage both civilian and military projects in the Atomic Energy Act of 1946 (P.L. 79-585).¹³ In response to the energy crisis, Congress subsumed the AEC, including the Manhattan project facilities, and other energy programs, into the Energy Research and Development Administration (ERDA), which became the focus for federal energy technology R&D, and the Nuclear Regulatory Commission (NRC) as part of the Energy Reorganization Act of 1974 (P.L. 93-438).¹⁴

In the Department of Energy Organization Act of 1977 (P.L. 95-91), Congress decided to combine the activities of ERDA with approximately 50 other energy offices and programs in a new Department of Energy (DOE), which began operations on October 1, 1977.¹⁵ In 1979, the Iranian Revolution precipitated the “second” energy crisis that took place from 1978-1981. High oil prices and inflation lasted for several years. An ensuing recession curbed demand and oil prices fell markedly by 1986. The scale of funding for most of DOE’s energy R&D programs dropped steadily during the 1980s (see **Figure 1**).

The large energy technology demonstration projects funded during the late 1970s and early 1980s were viewed by some as too elaborate and insufficiently linked to either existing energy research or the marketplace.¹⁶ A well known example is the Synthetic Fuels Corporation (SFC).¹⁷ The goal of SFC was to support large-scale projects that industry was unwilling to support due to the technical, environmental, or financial uncertainties. The program ended in 1986 due to a

¹² Energy Information Administration, “25th Anniversary of the 1973 Oil Embargo,” at [<http://www.eia.doe.gov/emeu/25opec/anniversary.html>].

¹³ U.S. Department of Energy, Office of History and Heritage Resources, “The Manhattan Project: An Interactive History,” “Civilian Control of Atomic Energy” webpage at [http://www.cfo.doe.gov/me70/manhattan/civilian_control.htm].

¹⁴ Department of Energy, “Energy Research and Development Administration,” webpage at [http://www.ch.doe.gov/html/site_info/energy_research.htm].

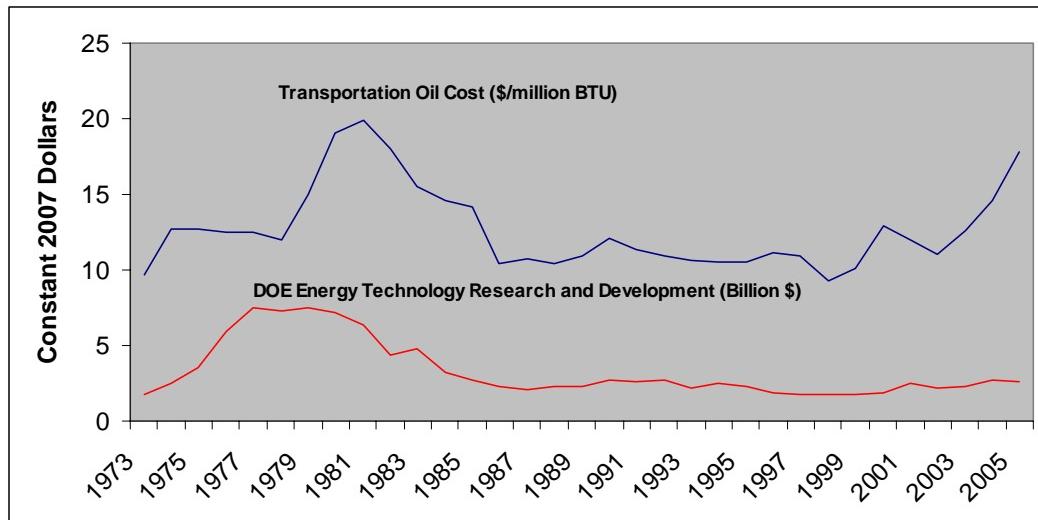
¹⁵ Although DOE did not begin operating until 1977, the term “DOE Energy Technology R&D Program” in this report is defined as encompassing DOE programs funded beginning in 1977 as well as energy R&D activities that occurred prior to 1977 that were managed by the organizations it subsumed.

¹⁶ See, for example, Bruce L.R. Smith, *American Science Policy Since World War II* (Washington, DC: Brookings Institution, 1990).

¹⁷ The Synthetic Fuels corporation was established by the United States Synthetic Fuels Corporation Act of 1980 (P.L. 96-294), and its operation was discontinued by the Synthetic Fuels Corporation Act of 1985 (P.L. 99-272).

combination of lower energy prices, environmental issues, lack of support by the Reagan Administration, and administrative challenges.¹⁸

Figure 1. Comparison of Consumer Transportation Oil Cost and DOE Energy Technology R&D Funding, 1973-2005



Source: Congressional Research Service. Transportation oil costs are from transportation/petroleum column of Table 3.4 Consumer Price Estimates for Energy by End-Use Sector, 1970-2005 in Energy Information Administration, Annual Energy Review 2007, Report No. DOE/EIA-0384(2007), Posted: June 23, 2008, at [http://www.eia.doe.gov/aer/finan.html]. DOE data is from CRS Report RS22858, *Renewable Energy R&D Funding History: A Comparison with Funding for Nuclear Energy, Fossil Energy, and Energy Efficiency R&D*, by Fred Sissine. Dollars for both transportation oil costs and DOE energy R&D were adjusted to 2007 dollars using the information from Bureau of Economic Analysis, Table 1.1.4. Price Indexes for Gross Domestic Product at [http://www.bea.gov/bea/dnipaweb/index.asp].

Oil prices began to rise substantially in 2004, but funding for energy technology R&D has not increased as it did during the energy crisis of the late 1970s to early 1980s. With oil prices reaching nearly \$150 per barrel in July 2008, some believe that the nation is in another energy crisis, while others believe that oil prices will moderate.¹⁹ In the 110th Congress, the policy debate regarding the magnitude and priorities for energy R&D continues — in response both to oil prices and to concerns about climate change, as energy-related activities are a major source of greenhouse gas emissions.²⁰

¹⁸ National Academy of Sciences, *The Government Role in Civilian Technology: Building a New Alliance* (Washington, DC: National Academy Press 1992).

¹⁹ See CRS Report RL33521, *Gasoline Prices: Causes of Increases and Congressional Response*, by Carl E. Behrens.

²⁰ For more information, see CRS Report RL34513, *Climate Change: Current Issues and Policy Tools*, by Jane A. Leggett.

Comparative Analysis of the Manhattan Project, the Apollo Program, and Federal Energy Technology R&D

A general understanding of driving forces of and funding histories for the Manhattan project and Apollo program, and a comparison of these two initiatives to Department of Energy (DOE) energy technology R&D programs, may provide useful insights for Congress as it assesses and determines the nation's energy R&D policy. Four criteria that might be used to compare these programs are funding, perception of threat, goal clarity, and technology customer. Each is discussed in more depth below.

Funding

Table 1 provides a comparison of the total and annual average program costs for the Manhattan project, Apollo program, and federal energy technology R&D program since the first energy crisis. Annual average long-term (1974-2008) DOE energy technology R&D funding was approximately \$3 billion (in 2007 constant dollars) as is the FY2008 budget and the FY2009 budget request.²¹ In comparison, the annual average funding (in 2007 constant dollars) for the Manhattan project was \$4 billion and for the Apollo program and the DOE energy technology program at its peak (1975-1980) was \$7 billion.

At the time of peak funding, the percentage of federal spending devoted to DOE energy technology R&D was half that of the Manhattan project, and one-fifth that of the Apollo program. From an overall economy standpoint, the percentage of the gross domestic product (GDP) spent on DOE energy technology R&D in the peak funding year was one-fourth that spent on either the Manhattan project or the Apollo program.

As shown in **Figure 2**, although cumulative funding for the DOE energy technology R&D program is greater than for the Manhattan project or the Apollo program, the annual funding for each of the historical programs was higher than that for energy technology R&D which occurred over a greater number of years. This is an important distinction: the Manhattan project and the Apollo program were specific and distinct funding efforts whereas the national energy R&D effort has been ongoing over a longer period of time. In all three cases, a rapid increase in funding was followed by a rapid decline.

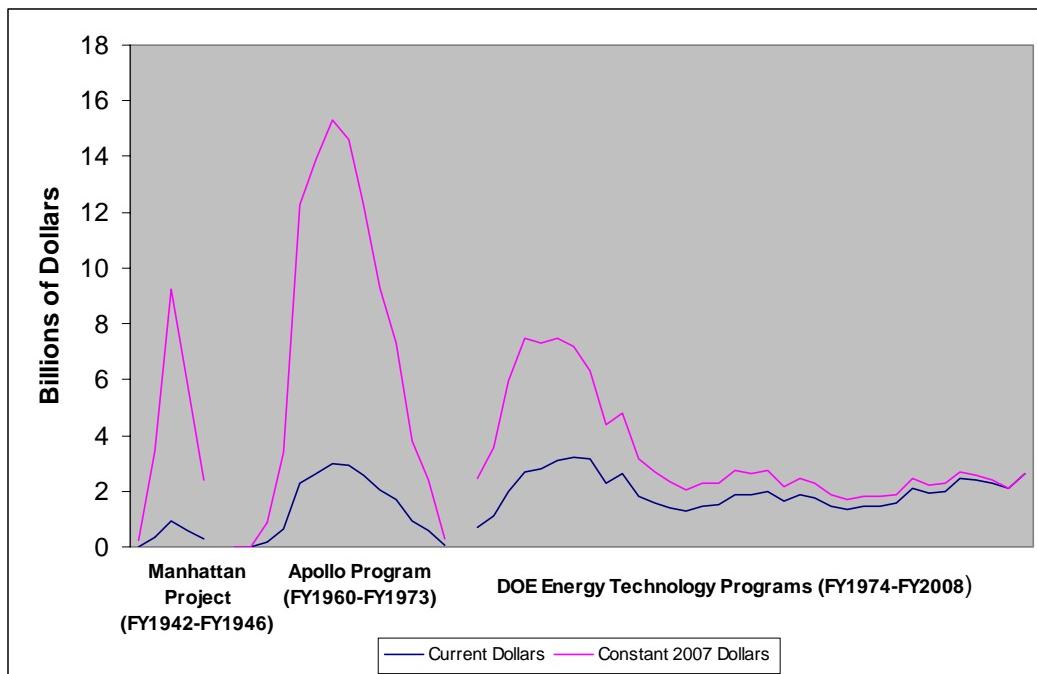
²¹ For information on the DOE energy technology R&D budget, see CRS Report RL34448, *Federal Research and Development Funding: FY2009*, coordinated by John F. Sargent.

Table 1. Cumulative and Annual Average Program Year Funding for the Manhattan Project, the Apollo Program, and DOE Energy Technology R&D Program

	Cumulative Funding (in billions of 2007 dollars)	Number of Fiscal Years	Annual Average Funding Per Program Year (in billions of 2007 dollars)	Percent of Federal Outlays During Year of Peak Funding	Percent of GDP During Year of Peak Funding
The Manhattan Project (1942-1946)	\$21	5	\$4	1.0	0.4
The Apollo Program (1960-1973)	\$96	14	\$7	2.2	0.4
DOE Energy Technology Programs (1975-1980) [Peak Funding]	\$41	6	\$7	0.5	0.1
DOE Energy Technology Program (1974-2008) [Long-Term Funding]	\$115	35	\$3	0.5	0.1

Source: Congressional Research Service. Manhattan Project data: Richard G. Hewlett and Oscar E. Anderson, Jr., *A History of the United States Atomic Energy Commission: The New World, 1939/1946, Volume I*. Apollo program data: Richard Orloff, *Apollo By The Numbers: A Statistical Reference*, NASA SP-2000-4029, 2004 web update. DOE data: CRS Report RS22858, *Renewable Energy R&D Funding History: A Comparison with Funding for Nuclear Energy, Fossil Energy, and Energy Efficiency R&D*, by Fred Sissine. Federal Outlay and Gross Domestic Product (GDP) data: Office of Management and Budget, *Historical Tables, Budget of the United States Government FY2009*. Peak year of funding (in current dollars) for Manhattan project was 1946, for Apollo program, 1966, and for DOE Energy Technology R&D programs, 1980. The greatest annual funding (in constant dollars) for DOE energy technology programs took place from 1975-1980.

Figure 2. Annual Funding for Manhattan Project, Apollo Program, and DOE Energy Technology R&D Program



Source: Congressional Research Service. Manhattan Project data: Richard G. Hewlett and Oscar E. Anderson, Jr., *A History of the United States Atomic Energy Commission: The New World, 1939/1946, Volume I*. Apollo program data: Richard Orloff, *Apollo By The Numbers: A Statistical Reference*, NASA SP-2000-4029, 2004 web update. DOE data: CRS Report RS22858, *Renewable Energy R&D Funding History: A Comparison with Funding for Nuclear Energy, Fossil Energy, and Energy Efficiency R&D*, by Fred Sissine.

Threat Perception

The Manhattan project and Apollo project were both responses to perceived threats, which compelled policymaker support for these initiatives. The Manhattan project took place during World War II. Although the public might have been unaware of the potential threat of Germany's use of nuclear weapons and the Manhattan project, the President and Members of Congress could feel confident about public support for the war effort of which the Manhattan project was a part. Similarly, the Apollo program took place during the Cold War with the Union of Soviet Socialist Republics (USSR). When the USSR launched the Sputnik satellite and first man into space, the U.S. public felt threatened by the potential that the USSR might take leadership in the development of space flight technology, and potentially greater control of outer space. President Jimmy Carter said that

With the exception of preventing war, this [energy crisis] is the greatest challenge that our country will face during our lifetime ... our decision about energy will test the character of the American people and the ability of the President and the Congress to govern this Nation. This difficult effort will be the

‘moral equivalent of war,’ except that we will be uniting our efforts to build and not to destroy.”²²

The threat to which investment in energy technology R&D responds, however, is largely economic rather than military. In addition, the threat posed by climate change, which is related to energy consumption, will likely be gradual and long-term.²³

Goal Clarity

Another issue is the degree to which there is clarity and consensus on the program goal. The Manhattan project had a clear and singular goal — the creation of a nuclear bomb. For the Apollo program, the goal was also clear and singular — land American astronauts on the moon and return them safely to Earth. In the case of energy technology R&D, however, the overall goal of clean, affordable, and reliable energy is multi-faceted. While “energy independence” has from time to time been a rallying cry, energy technology R&D has in fact, been driven by at least three not always commensurate goals: resource and technological diversity, commercial viability, and environmental protection. To help reduce the risk of dependence on a single energy source, diversity of resources and energy technologies have always been seen as a goal of the energy R&D program. Second, unlike the Manhattan project or the Apollo program, the DOE energy technology R&D program seeks ultimately to be commercially viable. Third, the energy R&D program must meet environmental goals, including reducing the impact of energy-related activities on land, water, air, and climate change.

Technology Customer

Another comparison criterion is the customer for technologies that may result from the R&D. The government was the customer for both the Manhattan project and Apollo program. The private sector is the ultimate customer for any energy technology developed as a result of federal energy R&D programs. Therefore, the marketability of any technologies developed will be a key determinant of the degree to which the program is successful. Moreover, the inherent involvement of the private sector raises a number of issues related to the appropriateness of different government roles. Some believe that focusing R&D on one particular technology versus another may result in government, instead of the marketplace, picking “winners and losers.”²⁴ Some experts believe that the most important driver for private sector deployment or commercialization is not the need for new technologies,

²² President Jimmy Carter, “Address to the Nation on Energy,” speech, April 18, 1977. A video and text is at [<http://millercenter.org/scripps/archive/speeches/detail/3398>].

²³ CRS Report RL34513, *Climate Change: Current Issues and Policy Tools*, by Jane A. Leggett.

²⁴ For more discussion of this issue, see CRS Report RL33528, *Industrial Competitiveness and Technological Advancement: Debate Over Government Policy*, by Wendy H. Schacht.

but regulation or economic incentives.²⁵ Others, however, believe that without government support and intervention, the private sector is unlikely to conduct the R&D necessary to achieve the public goal of clean, affordable, and reliable energy, and that current technologies are insufficient to achieve this goal.²⁶

Implications for Congress

When the Manhattan project and the Apollo program are used as analogies for future DOE energy technology R&D, the following points may be important to consider:

- To be equivalent in annual average funding, DOE energy technology R&D funding would need to increase from approximately \$3 billion in FY2008 to at least \$4 billion per program year to match the Manhattan project funding, or \$7 billion per program year to match Apollo program funding levels or DOE energy technology R&D funding at its peak. To be equivalent of peak year funding would require even greater increases. In terms of federal outlays, energy technology R&D funding would need to increase from 0.5% to 1% (Manhattan project) or 2.2 % (Apollo program) of federal outlays. As a percentage of GDP, this funding would need to increase from 0.1% to 0.4% of GDP (for both the Manhattan project and the Apollo program).
- Both the Manhattan project and the Apollo program had a singular and specific goal. For the Manhattan project, the response to the threat of enemy development of a nuclear bomb was the goal to construct a bomb; for the Apollo program, the threat of Soviet space dominance was translated into a specific goal of landing on the moon. For energy, however, the response to the problems of insecure oil sources and high prices has resulted in multiple, sometimes conflicting goals.
- Both the Manhattan project and the Apollo program goals pointed to technologies primarily for governmental use with little concern about their environmental impact; for energy, in contrast, the hoped for outcome depends on commercial viability and mitigation of the environmental impacts of the energy technologies developed.

Although the Manhattan project and the Apollo program may provide some useful analogies for funding, these differences may limit their utility regarding energy policy. Rather, energy technology R&D has been driven by at least three not always

²⁵ See for example, David Goldston, “Misspent Energy,” *Nature*, 447:130, May 10, 2007 at [<http://www.nature.com/nature/journal/v447/n7141/pdf/447130a.pdf>].

²⁶ See, for example, The National Academies, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington, DC: National Academy Press, 2007).

commensurate goals — resource and technological diversity, commercial viability, and environmental protection — which were not goals of the historical programs.